

A PROCEDURE FOR FORECASTING TORNADOES IN ALABAMA, GEORGIA, AND SOUTH CAROLINA

A. H. STAKELY

Eastern Air Lines, Inc., Atlanta, Ga.¹

[Manuscript received February 5, 1957; revised May 6, 1957]

ABSTRACT

An effective procedure is devised for determining by 0400 EST whether tornadoes will or will not occur within the area comprising the States of Alabama, Georgia, and South Carolina during the remaining portion of the day.

1. INTRODUCTION

A categorical answer as to whether or not a tornado will occur within the area of Alabama, Georgia, or South Carolina on a given day is the primary objective of this study. The approach to forecasting tornadoes in this area was made in a somewhat different manner than has been previously used by other investigators. Armstrong [1] used primarily the 700-mb. chart, while others [3, 4] used primarily upper-air soundings. The data used were those next prior to the time of occurrence. In this study the approach has been through the analysis of several levels which contribute to instability of the atmosphere over the tri-State area.

A check of available studies failed to show one which restricted the climatology of tornadoes to only Alabama, Georgia, and South Carolina. Therefore a survey of the tornado statistics of this area was made, to serve as a guide to forecasting requirements. Figure 1 shows the frequency of occurrence of tornadoes in this area by hours to the nearest hour of the day, during the years 1950 through 1955. (Eastern Standard Time is used throughout this study.) Data for years prior to 1950 were not used because it did not seem likely that they would include all tornadoes which had occurred. Figure 1 shows the preponderance of occurrences in the late afternoon over early morning hours. The peak at 1800 EST is twice that of a secondary peak at 0800 EST. The minimum between 2300 and 0300 EST indicated this is the period for which forecast coverage is least needed; therefore, a calendar day forecast is made using the 0130 EST surface map and 2200 EST upper-air data. By 0400 EST a forecast for the date in question can be made. Since only 4 percent of the tornadoes occur before 0400 EST, the few missed before this time are negligible in considering a forecast to be issued only once a day for an affirmative or negative answer on tornado occurrence during the rest of the day. No study has been made of the timing, although some observations on this will be made later.

¹ Project sponsored by U. S. Weather Bureau.

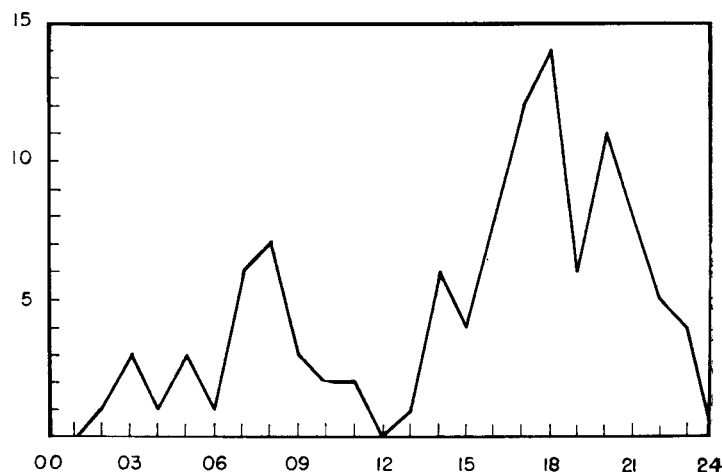


FIGURE 1.—Tornado occurrences relative to time of day for the years 1950 through 1955, January through August, for Alabama, Georgia, and South Carolina.

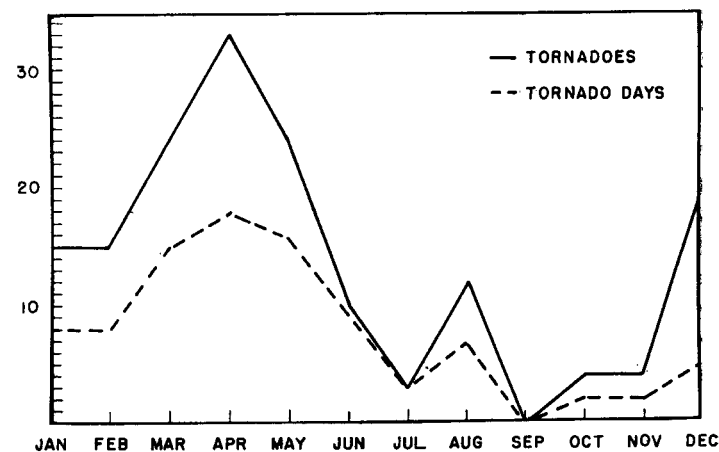


FIGURE 2.—Tornado occurrences plotted by months for the years 1950 through 1955 for Alabama, Georgia, and South Carolina.

Tornadoes were classified first as "family" and "isolated" types. While there is not sufficient evidence to prove the point, it seems likely that isolated tornadoes may be less intense. This classification, while not used

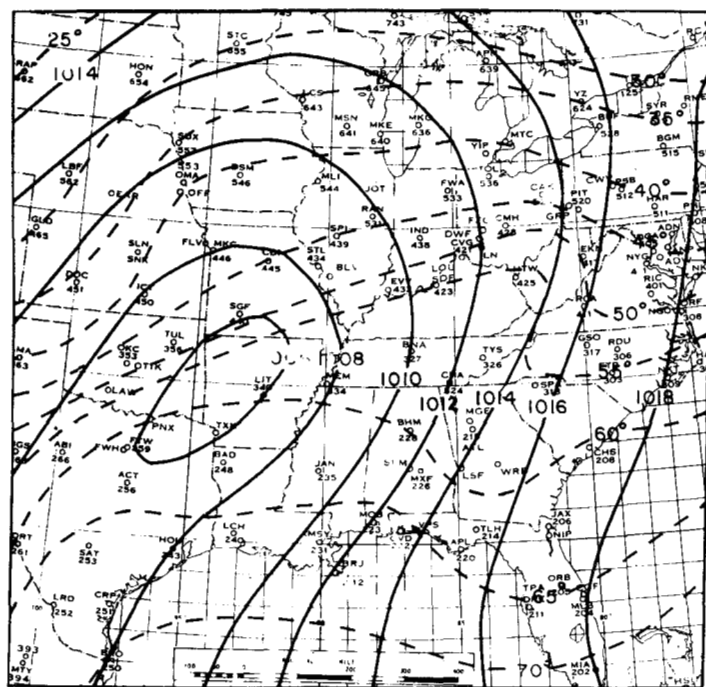


FIGURE 3.—A composite surface chart at 0130 EST for 10 "family" type tornado cases in the tri-State area.

in the portion of the study concerned with an affirmative or negative answer on occurrence, produced the observation that all South Carolina tornadoes are of the isolated type, and that June, July, and August tornadoes are isolated throughout the tri-State area.

From climatological considerations (fig. 2), the period of study was confined to January through May. The reason for omission of June, July, and August from the tornado season is obvious from figure 2. Data were not available for September through December. These months are also climatologically unfavorable. It is believed, however, that the findings of this study will be applicable to these months.

Every effort was made to make the forecast by strictly objective criteria. To a certain extent this has been carried almost to extremes, but the categorical result appears to justify this approach. The objective procedure is expressed by a work sheet which allows every day of the tornado season to be considered a potential tornado day until objectively eliminated. The period considered was the 907 days, January 1, 1950, through May 31, 1955, and thus in this study there are 907 cases. The process of elimination of "no threat" days is begun by using surface data; specifically, the 0130 EST surface map eliminates about 75 percent of all days as tornado-threat days. The detailed discussion follows.

2. SURFACE CHART

The dewpoint over the area in which tornadoes occur has previously been recognized as an important criterion. Rather than to attempt to forecast the dewpoint at a location in the area, when the desired location is unknown,

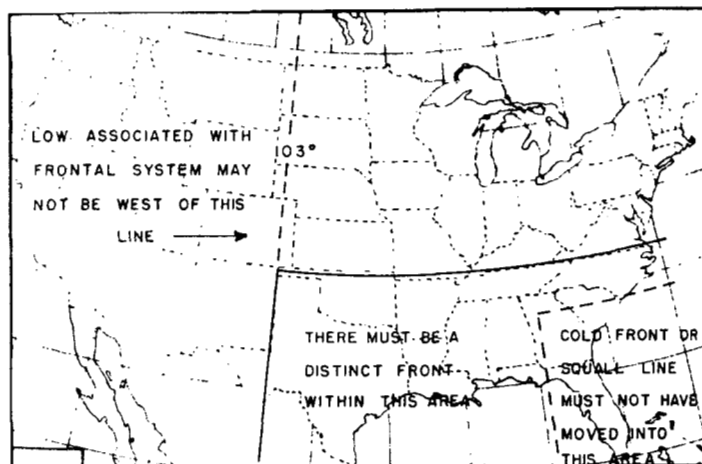


FIGURE 4.—Reference chart to be consulted when evaluating the surface cyclone and frontal positions on the 0130 EST chart. In order for a surface cyclone to be in a position favorable for tornadoes in the tri-State area it must be centered east of 103° W., and a portion of the front must lie within the area bounded by the solid lines along latitude 36.5° N. and longitude 103° W. Cold fronts or squall lines which are east of Atlanta, Ga., on the 0130 EST map preclude tornado activity on that day.

a large area was considered on the 0130 EST surface chart. If the dewpoint was 60° F. or more at any station along the Gulf coastal area from Biloxi, Miss. eastward to Jacksonville, Fla., or anywhere in the tri-State area, the first criterion for a tornado was met. This rule had no exception in the 907 cases.

The lowest value of the surface pressure observed in the tri-State area on the 0130 EST surface chart proved to be of real significance in separating cases. It was found that no tornadoes occurred when the lowest surface pressure in the tri-State area was 1018 mb. or above. This finding, combined with the dewpoint requirement above, eliminated 449 days from further consideration.

A composite surface chart of ten "family" type tornado days is shown in figure 3. From this chart a general idea of the location of frontal positions can be deduced as being associated with the general trough through Arkansas and Texas. The exact location of each front at 0130 EST was plotted on a separate map for each tornado date. These maps showed a wide variety of pattern, but several general features were noted. In every case, a definite frontal system was present within the area south and east of 36.5° N. latitude and 103° W. longitude, as shown in figure 4. In most cases it was a cold front. In quite a few cases there was an active squall line, and in many others there was a definite Low within or just south of the area. Conversely, in no case was the Low, in which the frontal system was located, centered farther west than 103° W. Also, the cold front or squall line should not have passed into the southeastern quadrant of Atlanta, Ga. Almost all cases had a portion of the frontal system, of the low center, south of the latitude of Atlanta. Hence, if a frontal system on the 0130 EST surface chart did not meet these limitations, the date became negative for

cold injection shown by the open arrow is near Amarillo, Tex.

It soon became apparent that this center of cold injection would be an advance indication of an area of instability. A check of cases which were not eliminated by previous criteria at this point showed that the cold injection center at the 850-mb. level was an important factor. Since an effort was being made to confine the forecast factors to the 2200 EST upper-air charts, there obviously had to be a modification to the cold injection idea to some extent. The centers of cold injection for all dates when a tornado occurred in the tri-State area are shown in figure 6. In addition, the centers of any other cold advection in the area were included when a definite cold injection was not present. This inclusion eliminated subjective considerations in choosing a cold injection center.

The value of the cold injection or advection center as a predictor of tornadoes is demonstrated by the fact that only one situation of multiple tornado occurrence was

recorded during the 6-year period without its presence in the proper area of figure 6. The very unusual case of March 22, 1953, in which cyclogenesis occurred behind the cold front, was the one failure of this parameter.

In those cases where a cold injection or advection center was apparent, its location was checked to see if it fell within the enclosed area in figure 6. Any center not within the area was sufficient to make the date negative for tornadoes. If a center was located in the area, but with the associated 850-mb. low center west of 103° W., the case was considered negative. These parameters eliminated nearly one-half of the remaining tornado threat days, that is, 76 out of the 163 left for consideration. Four actual tornado days were lost.

4. 700-MB. CHART

The composite 700-mb. chart of ten days when tornadoes of the "family" type occurred is shown in figure 7. No important criteria were developed from this level.

5. 500-MB. CHART

Ten "family" type tornado days were utilized in making the composite 500-mb. chart shown in figure 8. At this level it was found that whenever the trough line was located east of the Mississippi River, south of the Ohio River, no tornadoes occurred. A trough line as used here means a more or less north-south line followed by winds at this level of 270° or more northerly direction on the west side. (Note. Very minor perturbations were not considered.) This eliminated 7 days after lower-level criteria had remained favorable for tornadoes.

6. EXAMPLES AND REMARKS

Figure 9 shows the 0130 EST surface map of January 2, 1953. A similar surface map at 0130 EST on January 23, 1953 is shown in figure 10. The dewpoint condition was the only surface criterion for tornadoes missing from the chart in figure 9—the highest dewpoint observed within the tri-State area or in the group of stations from Biloxi, Miss. to Jacksonville, Fla. was 55° F. At Mobile, Ala. in figure 10 the dewpoint was 62° F. On January 23 there occurred a tornado in Alabama. No record of severe storms is found on the date of January 2.

To illustrate the effectiveness of the method outlined here, two different dates have been considered. The matter of time of year is eliminated by using the same date, February 20, in 1953 and 1954. Shown in figure 11 is the pertinent portion of the 0130 EST surface map in 1953 and in figure 15 the corresponding map in 1954. Both maps meet all surface requirements. In figure 12 is the 850-mb. chart associated with the surface chart in figure 11. The cold injection is quite distinct and the center is within the area outlined in figure 6. The contour on the 850-mb. chart (fig. 12) over Atlanta reaches the Gulf near Tallahassee. The same requirements are met for the 850-mb. chart for 1954 shown in figure 16

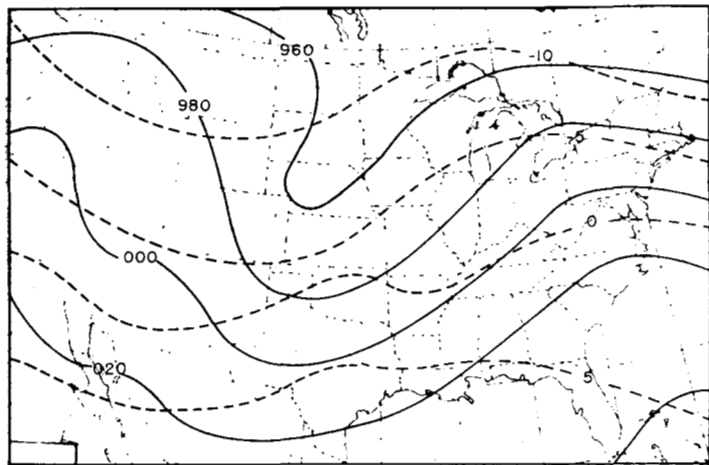
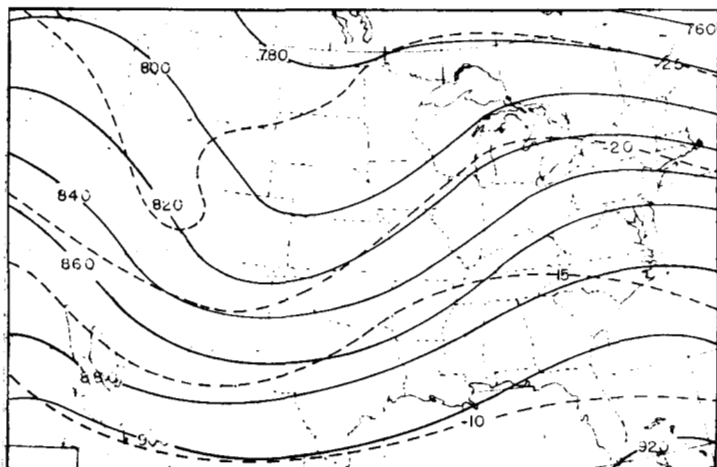


FIGURE 7.—A composite 700-mb. chart of 10 "family" type tornado dates using the 2200 EST data for the previous day. Solid lines are contours. Dashed lines are isotherms.



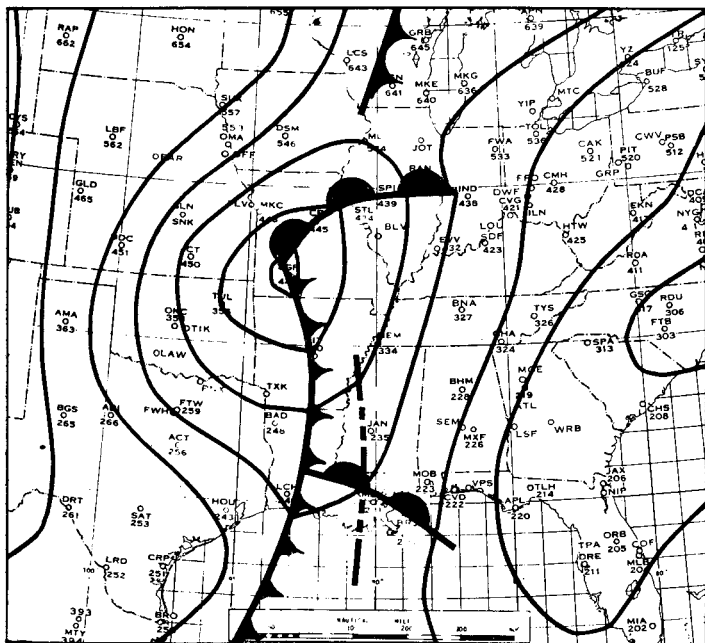


FIGURE 9.—Surface chart for 0130 EST, January 2, 1953. 55° F., at Biloxi, Miss., was the highest dewpoint within the tri-State area or the area from Biloxi to Jacksonville, Fla. All other surface criteria for tornadoes were met. No tornadoes were reported in Alabama, Georgia, or South Carolina on this date.

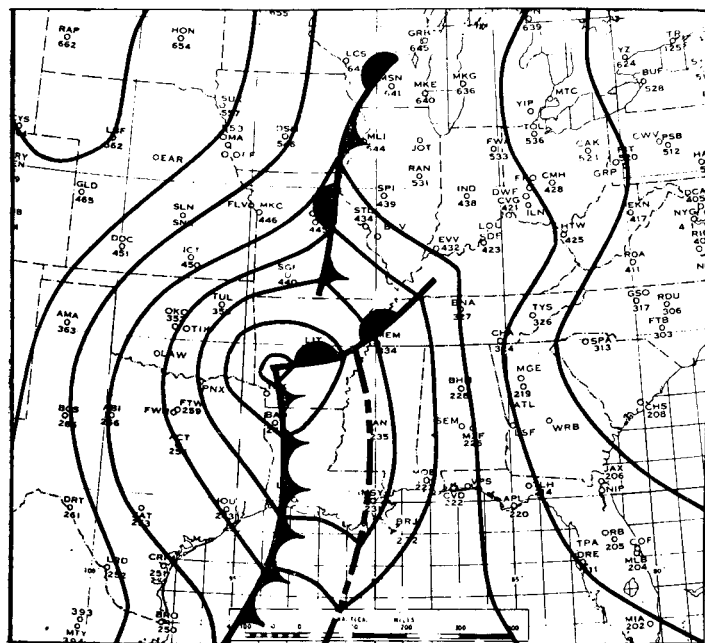


FIGURE 10.—Surface chart for 0130 EST, January 23, 1953. The dewpoint at Mobile, Ala., was 62° F. All other criteria for tornadoes were met. A tornado occurred in Clarke County, Alabama on this date.

which is the companion chart for figure 15. The 500-mb. charts did not show the trough line east of the Mississippi River on either of these two dates. Thus all criteria are favorable for a tornado forecast.

In figures 13 and 14 are shown portions of the 1330 and 1930 EST surface charts for February 20, 1953. A

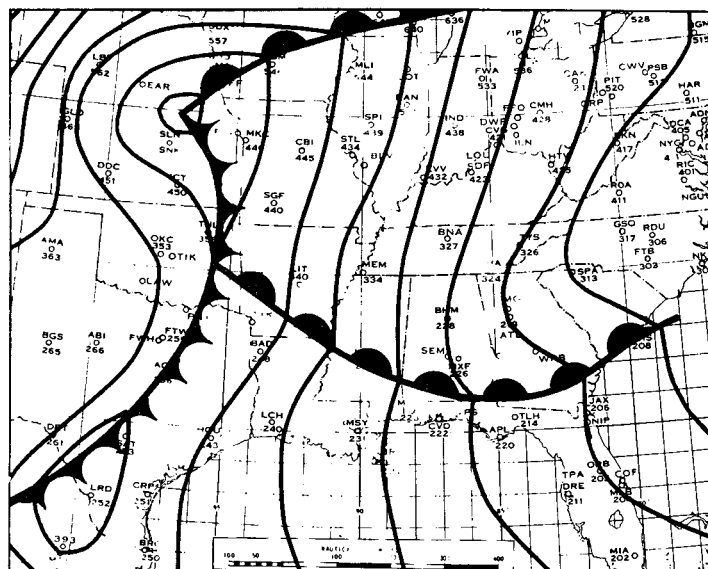


FIGURE 11.—Surface chart for 0130 EST, February 20, 1953. All criteria were favorable for tornadoes. Tornadoes occurred in Colbert, Marion, Walker, and Franklin Counties, Alabama.

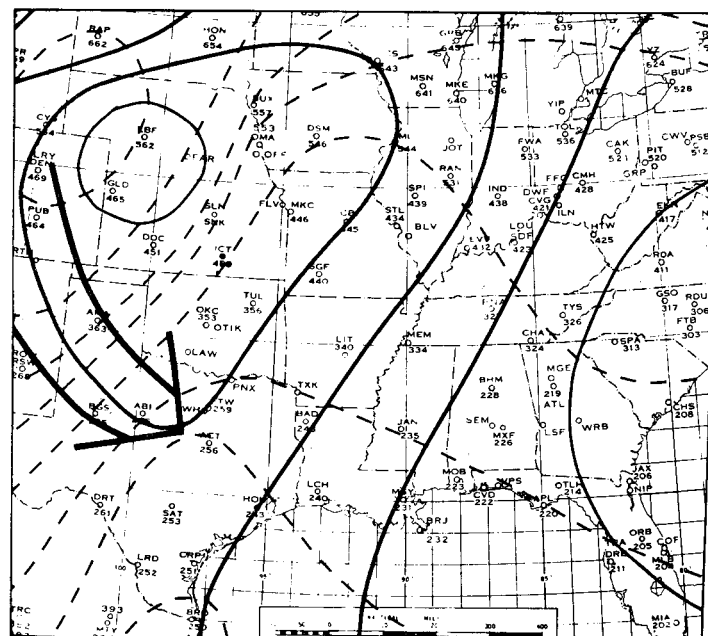


FIGURE 12.—850-mb. chart for 2200 EST, February 19, 1953. 200-ft. contours are shown as solid lines. Isotherms at 5° C. intervals are shown as dashed lines. The cold injection is shown by the open arrow.

family of four tornadoes was reported in west-central Alabama between 1730 and 2000 EST.

In figures 17 and 18 are shown portions of the 1330 and 1930 EST surface charts for February 20, 1954. Although the vicious line squall lasted until between 1330 and 1930 EST, and a tornado was reported in eastern Mississippi at 0235 EST, this case is recorded as a "miss" in this study. No record of a tornado is in the data for Alabama, Georgia, or South Carolina.

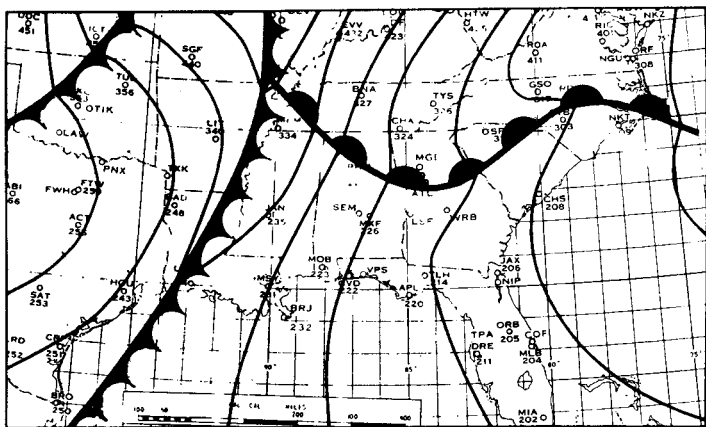


FIGURE 13.—Surface chart for 1330 EST, February 20, 1953.

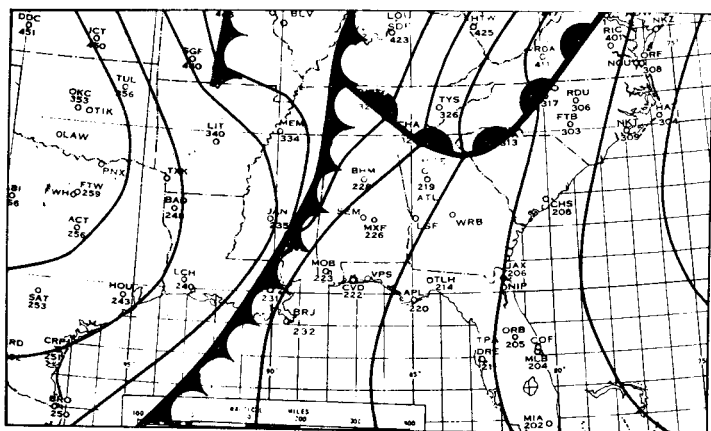


FIGURE 14.—Surface chart for 1930 EST, February 20, 1953.

7. FORECAST ACCURACY

The 41 days which would have a tornado forecast from the criteria developed in this study, but for which no record of a tornado is found, showed the following:

- On 28 of the days a squall line was present in the tri-State area.
- On 7 other days thunderstorms were shown on the 6-hourly synoptic charts.
- On 4 additional days thunderstorms or a squall line affected an immediately adjacent area.
- On 2 days only an active cold front without thunderstorms was shown on the 6-hourly charts.

This tabulation indicated that 97.5 percent of all tornado forecasts made by this method resulted in severe weather and 48.7 percent in tornadoes.

There were 10 tornado situations which this study missed by forecasting "no tornado". Mention has already been made of two of these; the dubious one at Cottageville, S. C., and the unusual case of cyclogenesis on March 22, 1953. Another date would have been correct from a practical sense, as the severe weather area was very limited in extent to only the Mobile Bay area

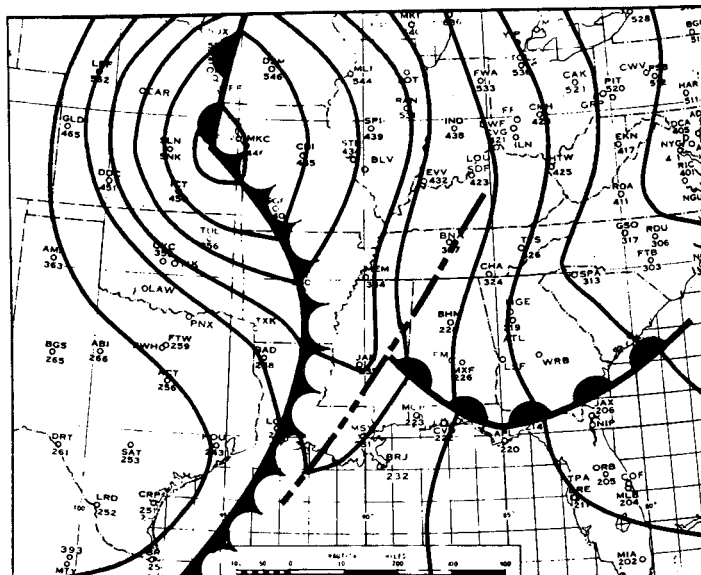


FIGURE 15.—Surface chart for 0130 EST, February 20, 1954. All criteria were favorable for tornadoes. Tornadoes were reported in Lamar, Covington, Jones, Newton, and Neshoba Counties, Mississippi. None occurred in Alabama, Georgia, or South Carolina.

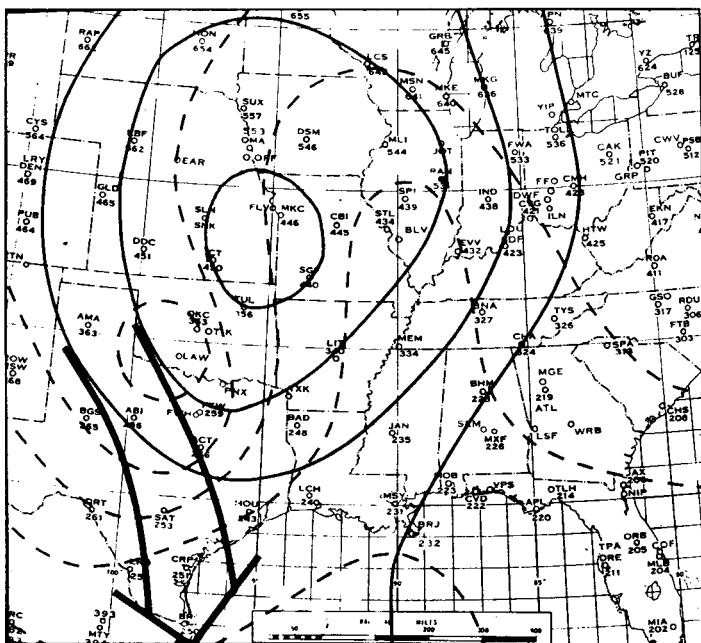


FIGURE 16.—850-mb. chart for 2200 EST, February 19, 1954. Contours are solid lines; isotherms, dashed lines. The cold injection is shown by the arrow.

and the storm occurred at 0245 EST. Six of the other seven were the "non-family" type of single occurrences. In only four cases would this study have led to misleading and damaging forecasts from a practical sense.

It was noted during the study that the time of occurrence was usually when the squall line passed, or if no

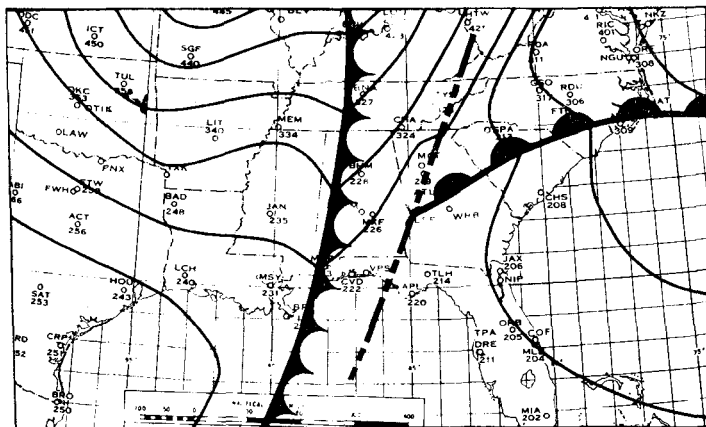


FIGURE 17.—Surface chart for 1330 EST, February 20, 1954.

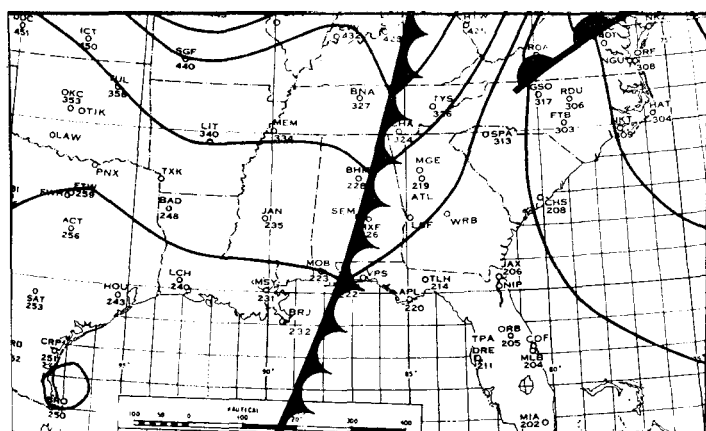


FIGURE 18.—Surface chart for 1930 EST, February 20, 1954.

squall line was present, when the cold front passed. This usually eliminates much of the area due to frontal location.

The 1955 data were used as an independent check initially, and then combined with the other years. The results for 1955 are given in table 1 and the results for combined years 1950-55 in table 2.

TABLE 1.—Results of application of forecast procedure to independent data, January-May, 1955

Tornado days forecast.....	10
Forecast correctly.....	8 (80.0 percent)
Actual tornado days.....	11
Forecast correctly.....	8 (72.7 percent)
No tornado days.....	139
Forecast correctly.....	137 (98.5 percent)
All days considered (incomplete data on one day).....	150
Forecast correctly.....	145 (96.6 percent)

		Forecast		
Observed		Tornado	No tornado	Total
	Tornado.....	8	3	11
	No tornado.....	2	137	139
	Total.....	10	140	150

TABLE 2.—Results of application of forecast procedure to combined dependent and independent data, January-May, 1950-55

Days considered—January through May 1950-55.....	907
Data from upper air charts unavailable.....	1
Days eliminated by dewpoint and pressure from surface chart.....	906
Days eliminated by fronts not in proper area.....	449
Days eliminated by improper gradient/geostrophic winds.....	457
Days eliminated by 850-mb. contour over Atlanta.....	186
Days eliminated by no cold injection or improper location.....	271
Days eliminated by 500-mb. trough too far east.....	41
	230
	67
	163
	76
	87
	7
	80

Tornado days forecast.....	80
Forecast correctly.....	39 (48.7 percent)
Actual tornado days.....	49
Lost by surface parameters.....	1 (Cottageville, S. C.)
Lost by 850-mb. parameters.....	48
	9
Successfully forecast.....	39
Actual tornado days.....	49
Forecast correctly.....	39 (79.5 percent)
No tornado days.....	858
Forecast correctly.....	817 (95.2 percent)
All days considered.....	906 (incomplete data on one day)
Forecast correctly.....	856 (94.5 percent)

		Forecast		
Observed		Tornado	No tornado	Total
	Tornado.....	39	10	49
	No tornado.....	41	816	857
	Total.....	80	826	906

8. WORK SHEET

The forecasting procedure developed in this study is summarized in the following work sheet:

Use 0130 EST surface map and 2200 EST 850-mb. and 500-mb. charts. Assume tornado alert for area of Alabama, Georgia, and South Carolina for the date until a "STOP" item is reached in right hand column.

STOP

1. If dewpoints of at least 60° F. or more are not found within the tri-State area nor on BIX-JAX line of stations, check STOP.....
2. If no surface pressure within tri-State area is lower than 1018 mb., check STOP.....
3. If there are no fronts in proper area in fig. 4, check STOP.....
4. If direction of geostrophic flow over area is 270° through north to 130°, check STOP.....
5. If gradient winds in tri-State area at 2200 EST (including TLH) are from 270° through north to 130°, check STOP.....
6. If the 850-mb. contour through Atlanta does not reach the Gulf coast, check STOP.....
7. If a center of cold injection or cold advection exists over lower Great Plains area at 850-mb., check area shown in fig. 6:
 - A. If center is outside of area, check STOP.....
 - B. If there is closed Low at 850 mb. associated with the injection and centered west of 103° W., check STOP.....
8. If the portion of the 500-mb. trough south of the Ohio River is east of the Mississippi River, check STOP.....

REFERENCES

1. H. Armstrong, "Forecasting Tornadoes in Georgia," *Monthly Weather Review*, vol. 81, No. 9, Sept. 1953, pp. 290-298.
2. R. G. Beebe, "Forecasting Winter Precipitation for Atlanta, Ga.," *Monthly Weather Review*, vol. 78, No. 4, Apr. 1950, pp. 59-68.
3. E. J. Fawbush and R. C. Miller, "A Mean Sounding Representative of the Tornadic Airmass Environment," *Bulletin of the American Meteorological Society*, vol. 33, No. 7, Sept. 1952, pp. 303-307.
4. E. J. Fawbush and R. C. Miller, "The Types of Airmasses in which North American Tornadoes Form," *Bulletin of the American Meteorological Society*, vol. 35, No. 4, Apr. 1954, pp. 154-165.
5. J. J. George, "The Prediction of Cyclogenesis," *Geophysical Research Papers* No. 23, "Forecasting Relationships between Upper Level Flow and Surface Meteorological Processes," Geophysics Research Directorate, U. S. Air Force Cambridge Research Center, 1953, pp. 21-50.